EE/MatE 129
MOS-1

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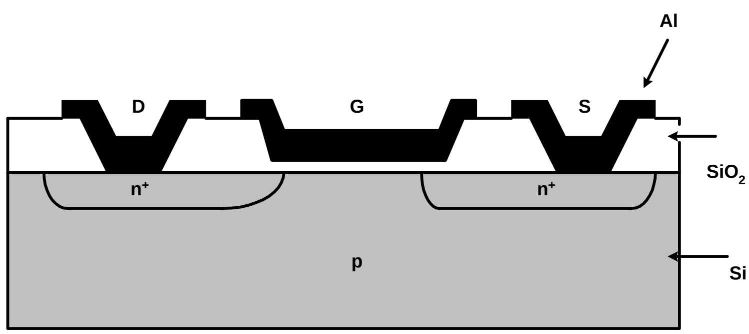
MOSFET Overview

- What is a MOSFET?
- Why use MOSFETs?
- MOSFET Physics
  - Energy Bands
  - Diode
  - MOS Diode
  - MOFET

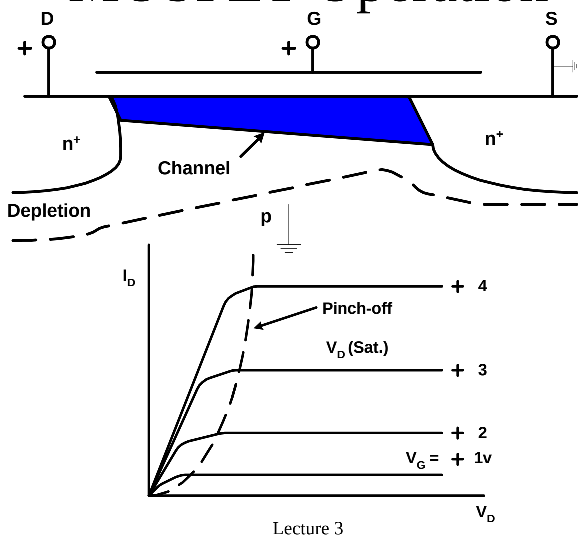
What is a MOSFET?

- Metal (or poly-silicon doped heavily to act like a metal)
- Oxide (SiO_2, Acts as an insulator.)
- Semiconductor (One can selectively change the carrier type to n-type or p-type.)
- Field Effect (Device is controlled by an electric field as opposed to current.)
- Transistor (Three terminal device)

MOSFET Cross Section



MOSFET Operation



Why use MOSFETS?

- The controlling terminal (the gate) uses minimal power to maintain its state (on or off)
  - The gate is a MOS structure with the oxide acting as an insulator. The only power used is to charge and discharge the gate capacitance.
  - Power is dissipated as heat to the lattice
    - Slows down device below specified clock speed.
- This allows more transistors per die.

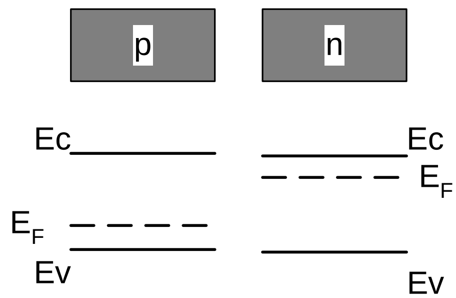
Why use MOSFETS?

- Other types of transistor logic are inherently faster, but these logic gates (ECL) use too much power to integrate the same complexity on a die as one can achieve with MOSFETS.
- CMOS logic goes ‘rail to rail’ with out regeneration circuitry.

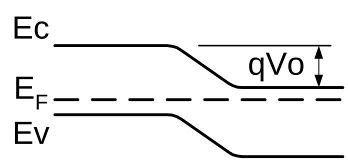
MOSFET Physics

- Solitary atoms of silicon have discrete energy levels that electrons can occupy.
- As Si atoms become closer, these levels start to interact and in according to the Pauli Exclusion Principle the discreet levels turn into bands.
  - The Conduction Band: Electrons promoted to this level are free to move under drift or diffusion.
  - The Valence Band: Electrons that are promoted to a trap in the forbidden region leave behind holes that are free to move under drift or diffusion

Energy Bands



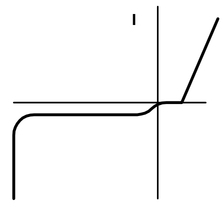
Energy Bands



Energy Bands

Particle flow		Current flow
⟶	Hole Diffusion	⟶
⟵	Hole Drift	⟵
‹— — — —	Electron Diffusion	— — — —›
— — — —›	Electron Drift	‹— — — —

Diode



- A Diode allows current flow in one direction (forward bias), but not in the other (reverse bias).
  - Forward Bias: The applied bias lowers the built in potential allowing diffusion or carriers across the junction.
  - Reverse Bias: The applied bias increases the barrier blocking further diffusion of carriers.

MOS Diode

- Metal Gate, Oxide insulator, Semiconductor
- Operation:
  - Apply a voltage to the gate and it attracts carriers of opposite polarity to the applied voltage.
  - One can attract carriers that are opposite to the semiconductor type.
  - V_T For a large enough voltage one can change the material from n-type to p-type or p-type to n-type near the oxide gate. The voltage at which this inverted region has the same carrier concentration as the substrate is V_T.

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MOSFET

- Two diodes, biased back to back, one diode is all ways reversed biased so no current can flow.
- If a MOS diode is placed in between, a conducting channel can be created thus allowing current to flow based on a gate voltage

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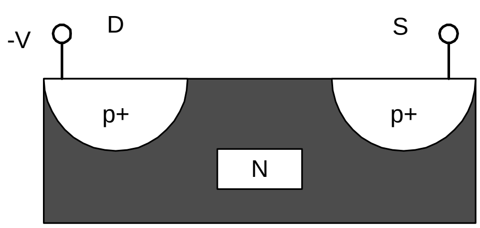

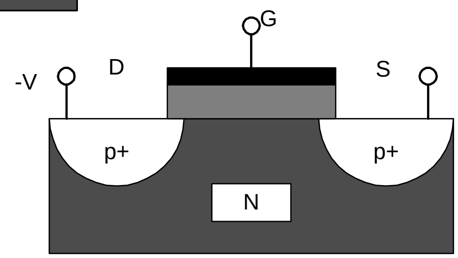

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Next Time

- V_T calculation
- IV characteristics
- PMOS Inverter